7 Evaluation of Navigation Channel Alternatives[1]

The objective of this study is to determine the engineering feasibility of maintaining a reliable navigation channel through the entrance to Willapa Bay. This chapter discusses the factors or criteria relevant for judging navigation reliability. In addition to navigation safety, selection of feasible alternatives also involves the cost of dredging, both through possible beneficial uses of the dredged material and through the stability of the adjacent beach as part of the overall inlet system.

The preceding chapters and associated appendices describe technical details and results of the individual study tasks that generated information for evaluating alternative channel designs. This chapter summarizes those results and adds integrating interpretations. Material is presented in tabular and graphical form concerning the following general categories:

a. Project operation and maintenance.

b. Navigation safety.

c. Environment and beneficial uses.

Project operation and maintenance is listed first because if the project is too costly, it cannot go to construction, so that navigability is not an issue. Such reasoning was applied in the screening process that reduced the original 19 alternatives to a smaller number for detailed evaluation.

Alternatives

The alternatives are described in Chapter 2. The screening process presented in Chapters 5 and 6 and elsewhere in the report produced three basic alternative groups, as shown in Figure 7-1. Depths are referenced to mean lower low water (mllw).

(1) North Fairway:

Alternative 3A: 28 ft-deep by 500 ft-wide channel, fixed location.

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[1] Written by Mr. William C. Seabergh and Dr. Nicholas C. Kraus, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS, and by Mr. Hiram T. Arden, U.S. Army Engineer District, Seattle, Seattle, WA.

Alternative 3B: 28-ft-deep by 500 ft-wide migrating channel, with minimum 1,500-ft width in S-curve.

Alternative 3F: 38-ft deep by 1,000-ft wide channel, fixed location.

Alternative 3G: 38-ft deep by 1,000 ft wide migrating channel, with minimum 1,500-ft width in S-curve.

(2) State Route (SR)-105 alternatives:

Alternative 3H-a: 28-ft deep by 500 ft-wide channel.

Alternative 3H-b: 28 ft-deep by 500 ft-wide channel, with the SR-105 dike raised from 18 ft mllw depth to 2 ft mllw depth.

(3) Middle Fairway:

Alternative 4A: 28 ft-deep by 500 ft-wide channel.

Alternative 4E: 38 ft-deep by 1,000 ft-wide channel.

Alternatives 3H-a and 3H-b were included for evaluation after new bathymetric measurements made during the course of this study indicated some deepening of the south side of the north channel just seaward of the SR 105 project. These two alternatives were added to determine if any advantages could be found in placing a navigation channel in this vicinity. Figure 7-1 shows the alternatives.

Criteria for Evaluation of Navigation Channel Alternatives

The criteria for evaluating the various channel alternatives were separated into three groups, as listed in Tables 7-1, 7-2, and 7-3. Table 7-1, dealing with operation and maintenance, comprises factors indicating estimated and calculated sediment volumes requiring removal from the navigation channel. In Willapa Bay, the high-energy waves, large tidal range, and strong tidal current, coupled with environmental considerations, combine to give relatively small windows of opportunity for dredging during the year. Evaluation of alternatives must consider the amount of maintenance dredging required both for the cost involved and the limited time dredging can be performed.

Two approaches were taken for evaluating the magnitude of sediment that would need to be dredged to maintain a safe and navigable channel for the subject alternative. A geomorphic approach examined long-term or life-cycle project dredging requirements. This life-cycle dredging was based on a 50-year project lifetime, and estimates were developed from results of Chapter 3. The second factor for the operation and maintenance evaluation came from the results of the numerical modeling discussed in Chapter 6. Volumes deposited in the channel during a representative severe winter storm and volumes deposited during a 31-day period of “typical” oceanic conditions defined the conditions for this evaluation.

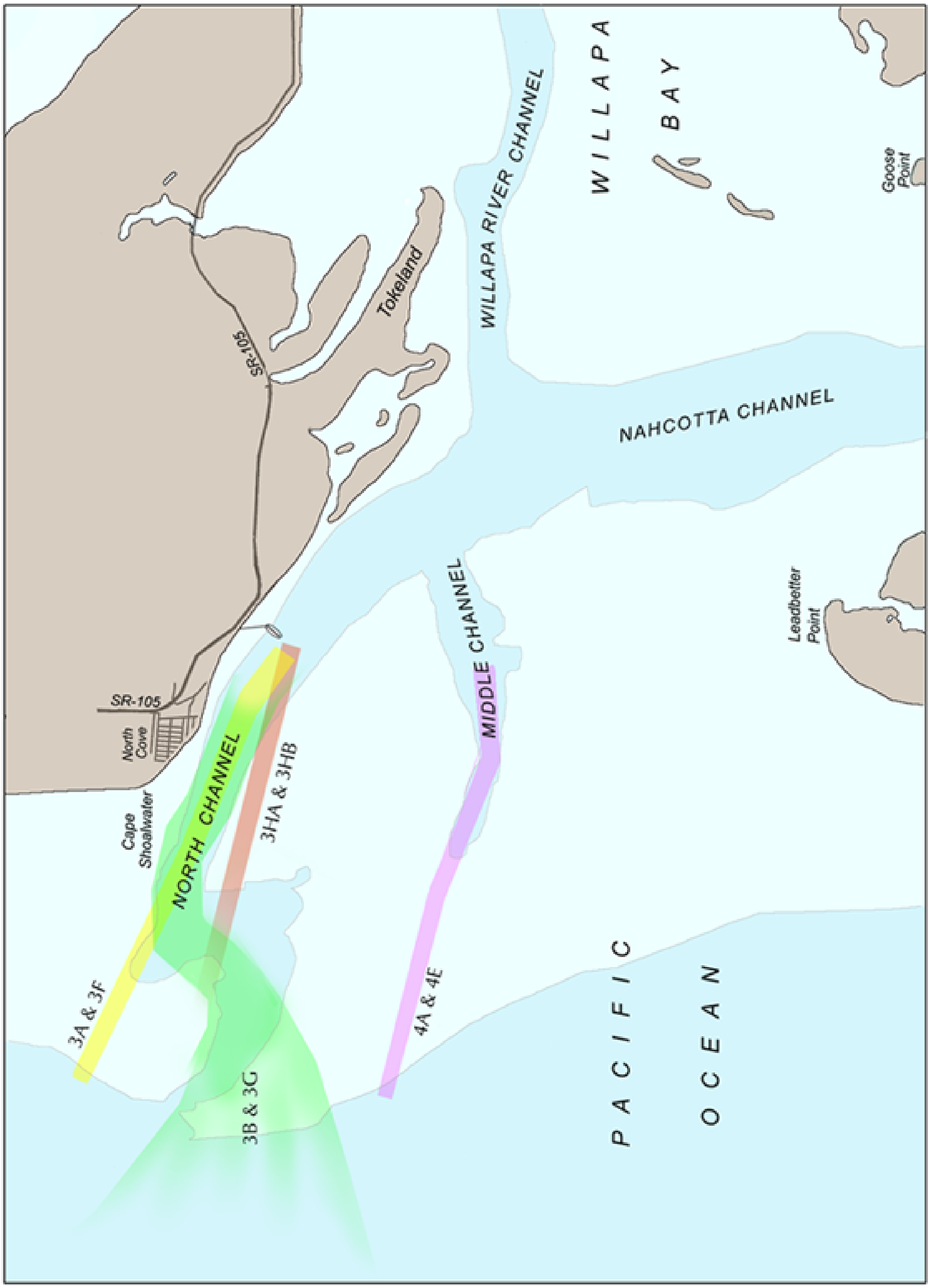

Figure 7-1. Alternatives for evaluation

Another factor of operation and maintenance relates to the estimated cost for surveying the inlet channel. The U.S. Army Corps of Engineers must provide guidance to the U.S. Coast Guard (USCG) for marking channels to identify safe access through the inlet. Before moving any channel markers, the USCG must receive a channel survey. An Alternative which has a less stable location or requires surveying under relatively more severe wave conditions will cost more to survey. The variations in these costs were not significant enough with respect to the costs associated with dredging, and were not included in Table 7-1.

Table 7-2 lists navigation safety factors. The first criterion is derived from results of the modeling of surface waves (Chapter 5) and the discussion of wave direction with respect to channel orientation in Chapter 2. Wave heights averaged along the channel are included in the table for 9-ft incident ocean waves. This wave height was considered a typical operational maximum for tug-and-barge traffic. Wave angles greater than 45 deg with respect to the channel axis are considered problematic for vessels. The Certainty of Depth factor evolved from the historic analysis of channel location discussed in Chapter 3 and channel capacity to maintain a 28-ft depth. Information contributing to the Channel Curvature and Variation in Location factor was developed from the historical analysis of Chapter 3. Information for the Alignment of Current With Channel factor was determined by examining visual results of numerical simulations of combined tidal circulation and surface waves model (Chapter 6).

Information contained in Table 7-3 concerns beneficial-use factors of dredged material and erosion potential at North Cove. Potential dredged-material placement sites are discussed in Appendix H. These results led to an overall examination of the sites for each alternative, based on availability, cost, capacity, and beneficial use. Numerical modeling of tidal currents provided information to compare with existing conditions for North Cove Erosion Potential.

The Evaluation

Table 7-1 summarizes the evaluation of the operation and maintenance factors considered. The "1998 Initial Dredging Volume" is the first item following the "Description" column. Presently, the S-curve channel of Alternative 3B requires minimal dredging, because it is the existing configuration. It is now in a filling mode, however, because as the "Annual Net Shoaling in Location of Potential Channel" column indicates, 1.0 million cu yd of fill occurred between 1998 and 1999. Alternative 3A requires 800,000 cu yd of dredging and is in a scour mode, as this potential location had 1.1 million cu yd of scour in the 1998-1999 time period. The deeper versions of Alternatives 3A and 3B, 3F and 3G, because of the greater initial depth, require 5.7 and 4.2 million cu yd of dredging, respectively. Alternatives 3H-a and 3H-b both require 2.1 million cu yd of dredging. The middle channel locations of Alternatives 4A and 4B need 2.2 and 12.0 million cu yd of initial dredging, respectively.

Following the aforementioned columns is the "50-Year Lifetime Maintenance Dredging Estimate," showing the projected amounts of dredging over a 50-year project lifetime, based on the geomorphic analysis of Chapter 3. The volumes are presented as an estimated range of values which could occur for a specific Alternative. The migrating channel Alternative 3B has the smallest amount, a 27-48 million cu yd range over 50 years, but would probably have the greatest likelihood of providing unsatisfactory navigation conditions, as is discussed below. Alternative 3G, also a migrating channel that is deeper and wider than 3B, has an estimated range of 58-102 million cu yd over 50 years. Alternatives 3A, 3H-a, 3H-b, and 4A all have lifetime estimated shoaling volume range of 42-74 million cu yd. The deeper and wider channel of Alternative 3F has a lifetime shoaling estimate in the range of 114-185 million cu yd. These shoaling volumes are converted to annual rates and compared to numerical model results in the next paragraph.

The numerical model results of channel shoaling in Chapter 6 are listed in the sixth and seventh columns of Table 7-1. The typical condition, 31-day simulations of channel shoaling, and the 15-day storm results are shown. Alternatives 3H-a, 3A, 4A, and 3H-b were reasonably close to one another in channel shoaling. Alternative 4E had slightly greater shoaling than the previously mentioned Alternatives, and Alternatives 3F, 3B, and 3G had progressively increasing amounts of channel shoaling. To compare the geomorphic and numerical modeling results, a yearly estimate of shoaling was determined from the geomorphic 50-year estimates and, using the following procedure, the numerical results provided an annual channel shoaling estimate: the 15-day storm period was multiplied by a factor of 4 to represent a 60-day period, and the 31-day typical values were multiplied by 10 to represent a 310-day period. Adding the two shoaling results produced a yearly estimate plotted in Figure 7-2. Shoaling rates of the two approaches were in reasonable agreement except for the migrating channel Alternatives 3B and 3G, where the geomorphic approach allows channel movement until channel curvature approaches 1998 conditions. Therefore, dredging is minimal until strong channel curvature is present and the channel must be realigned.

Capacity of a channel is another central aspect in the evaluation of channel shoaling. In the past, typical dredging did not produce a channel that would maintain depth or alignment for the time span between dredging. This is the reason the wider and deeper plans of Alternatives 3F and 3G were included in the evaluation. The wider footprints of these channels capture more sediment (shoaling), but the increased capacity will produce longer time periods of navigable depth and alignment.

Table 7-2 presents navigability safety factors. The entries in this table derive from the wave tests of Chapter 5 (third and fourth columns, "Wave Height and Angle"), the historic analysis of Chapter 3 (fifth and sixth columns, "Likelihood of Maintaining Depth Over Bar," and "Channel Curvature and Variation in Location," respectively), and the tidal and wave-generated current modeling of Chapter 6 ("Alignment of Current With Channel"). In the wave height and angle columns, the large wave angles with respect to channel orientation of Alternatives 3B and 3G are highly undesirable. Alternatives 3H-a and 3H-b had small wave angles but slightly greater wave heights than Alternatives 3A, 3F, 4A, and 4E.

As shown in the "Likelihood in Maintaining Depth Over Bar" column of Table 7-2, the historic analysis favors deeper dredged and migrating northern channel Alternatives 3B, 3F, 3G, and 3H, for certainty of depth, and the middle

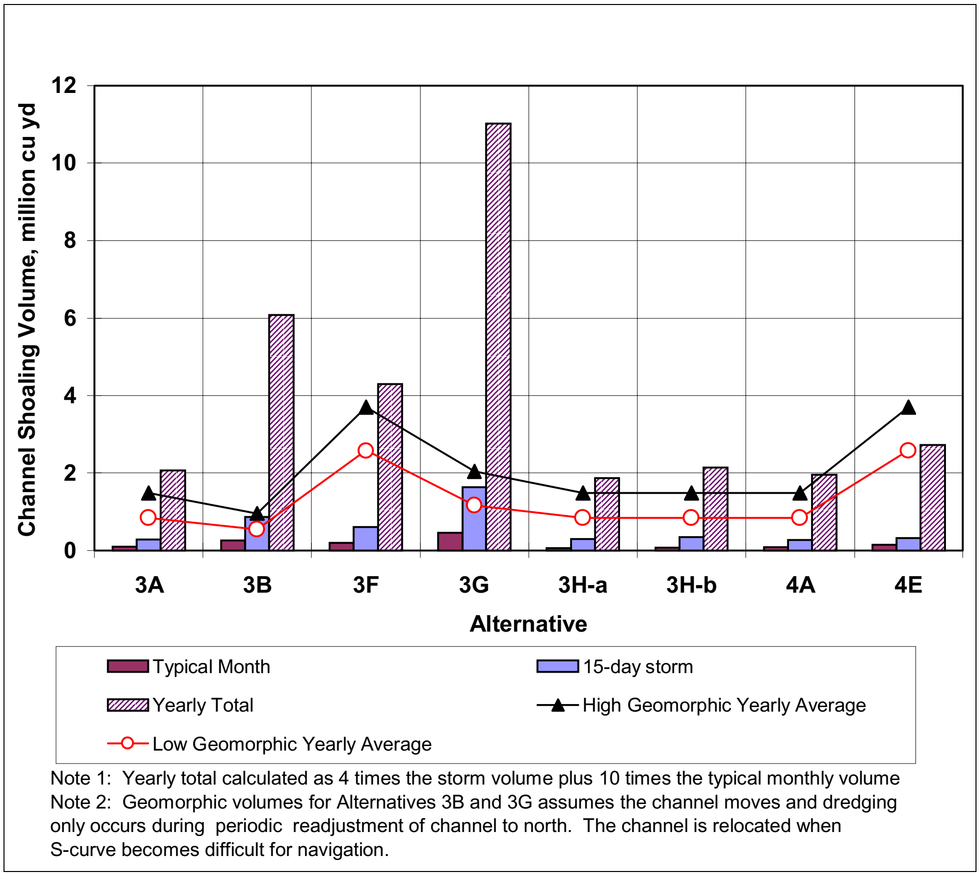

Figure 7-2. Yearly shoaling estimates based on geomorphic analysis and numerical modeling

channels less favorably. As far as "Channel Curvature and Variation in Location" ratings, Alternative 4E is highest because of its large width and depth, and its distance from the migrating northern spit. Alternatives 3A, 3F, 3H, and 4A are considered to have reasonable success at maintaining alignment and location through dredging activity.

The fourth factor of "Alignment of Current With Channel," evaluated in Table 7-2, was determined from results in Chapter 6. Good alignment of the currents with the channel is critical for tugs towing non-powered barges. Alternatives 3A, 3F, and 4A have good flow alignment with the channel. The other alternatives have reasonable alignment except for Alternative 3B, which has the strongest crosscurrents.

Table 7-3 compares alternatives for "Beneficial Use of Dredged Material and Erosion Potential." The evaluation of dredged-material disposal sites presented in Appendix H and summarized in Chapter 2 were consulted for this table. The straight northerly channel routes of Alternatives 3A, 3F, 3H-a, and 3H-b tend to rate higher overall with regard to proximity to available disposal sites and beneficial usage for the dredged material. Alternatives 3B and 3G are at a slightly greater distance from the optimal disposal sites. Alternatives 4A and 4E require sidecast dredging or use of the Goose Point disposal site.

Table 7-1
Design Alternative Evaluation, Willapa Bay Navigation Channel Reliability Study[1], Operation and Maintenance Factors

Alternative	Description	Estimated Dredging and Maintenance – Life cycle (Geomorpologically Based), million cu yd			Sediment Transport into the Channel-Event/Short Term (Numerical Model), cu yd		Comments
		1998 Initial Dredging Volume	Annual Net Shoaling in Location of Potential Channel, 1998-1999	50-Year Lifetime Maintenance Dredging Estimate	Typical Conditions for 31 Days	Jan 98 Storm for 15-day Storm	
1	1998 existing condition						Dredging not being performed at this time. Recent (1957-1974) yearly historical amounts were as high as 610,000 cu yd, yet not maintaining a safe navigable channel for a significant time period over the dredging cycle.
3A	Dredge primarily on entrance bar, straight out and fixed in position	0.8	-1.1 (scour)	42-74	95,000	280,000	Moderate initial cost relative to others. Sediment transport into channel next to lowest.
3F	Same as 3A, except dredge to total depth of 38 ft and with width 1,000 ft	5.7	-3.8 (scour)	114-185	190,000	600,000	Lifetime dredging based on complete sediment filling and does not consider possible improved flushing of sediment from channel. Moderate sediment influx and large footprint.
3B (Migrating channel)	Modified S-curve (moderate curve)	0.04	1.0 (fill)	27-48	260,000	870,000	Significant amounts of sediment transport into channel, but channel has large footprint to absorb influx and channel allowed to migrate.
3G (Migrating channel)	Same as 3B, except dredge to total depth of 38 ft and with width 1,000 ft	4.2	2.4 (fill)	58-102	450,000	1,630,000	Significant amounts of sediment transport into channel, but channel has large footprint to absorb influx and channel allowed to migrate.
3H-a	Existing SR-105 dike	2.1	-0.8 (scour)	42-74	66,000	300,000	Minimal sediment influx. Moderate startup cost.
3H-b	SR-105 dike raised to -2 ft (3H-b)	2.1	-0.8 (scour)	42-74	78,000	340,000	Slightly higher sedimentation than 3H-a. Construction cost for raising dike. Moderate initial dredging cost.
4A	Dredge primarily on entrance bar	2.2	0.1 (fill)	42-74	87,000	270,000	Minimum channel sedimentation. Low storage capacity of channel. Moderate initial dredging.
4E	Same as 4A, except dredge to total depth of 38 ft and with width 1,000 ft	12.0	1.2 (fill)	114-185	144,000	320,000	Lifetime dredging based on complete sediment filling and does not consider possible improved flushing of sediment from channel. Large footprint and storage capabilities. High startup cost.

[1]. Note: All channel depths are 26 ft mllw + 2 ft over-dredging (500 ft width at bottom) unless otherwise specified.

Table 7-2
Design Alternative Evaluation, Willapa Bay Navigation Channel Reliability Study[1], Navigability Safety Factors

		Wave Height and angle		Likelihood of Maintaining Depth Over Bar	Channel Curvature and Variation in Location	Alignment of Current with Channel	
Alternative	**Description**	**Average Along-Channel Significant Wave Height**	**Average Wave Angle at Worst Location**	**Certainty of Maintaining Depth Over Bar Between Dredging Cycles**	**Long-term Probability of Maintaining a Straight Channel**	**Do the Currents Safely Follow the Channel or are there Significant Cross-Currents**	**Comments**
1	1998 existing condition	1.3 m	30 deg	Low certainty	Very low	Fair alignment	Typical "S-curve" condition very difficult for safe navigation.
3A	Dredge primarily on entrance bar, straight out and fixed in position	1.4 m	23 deg	Moderate certainty	Good	Very favorable alignment	Overall good navigability.
3F	Same as 3A, except dredge to total depth of 38 ft and with width 1,000 ft	1.4 m	23 deg	High certainty	High	Very favorable alignment	Best Alternative with respect to navigability.
3B (Migrating channel)	Modified S-curve (moderate curve)	1.7 m	51 deg	High certainty	Very low	Poor alignment	Wave angle with vessel greater than 45 deg. Channel is not straight but 1,500-ft width in s-turn provides increased safety.
3G (Migrating channel)	Same as 3B, except dredge to total depth of 38 ft and with width 1,000 ft	1.7 m	51 deg	Highest certainty	Low	Poor alignment	Wave angle with vessel highly undesirable.
3H-a	Existing SR-105 dike	1.8 m	14 deg	Moderate certainty	High probability	Favorable alignment	Good alignment with respect to wave angle. Would anticipate improved alignment with current.
3H-b	SR-105 dike raised to elevation -2 ft (3H-b)	1.8 m	14 deg	High certainty	Good probability	Fair alignment	Good alignment with respect to wave angle. Would anticipate improved alignment with current.
4A	Dredge primarily on entrance bar	1.4 m	26 deg	Low certainty	Good probability	Very favorable alignment	Historical records do not support good depths in Middle Channel.
4E	Same as 4A, except dredge to total depth of 38 ft and with width 1,000 ft	1.4 m	26 deg	Moderate certainty	Very high	Fair alignment	Historical records do not support adequate depths in Middle Channel.

[1] Note: All channel depths are 26 ft mllw + 2 ft over-dredging (500 ft width at bottom) unless otherwise specified.

Table 7-3
Design Alternative Evaluation, Willapa Bay Navigation Channel Reliability Study[1], Beneficial Use of Dredged Material and Erosion Potential

		Dredging Disposal Sites	North Cove Erosion Potential	
Alternative	**Description**	**Availability, Cost, Capacity and Beneficial Uses**	**Erosion Potential by Tidal Current Erosion**	**Comments**
1	1998 existing condition	Good availability of sites, but no dredging being performed, so no beneficial uses.		Due to minimal dredging, good availability of disposal sites
3A	Dredge primarily on entrance bar, straight out and fixed in position	Reasonable availability and capacities available, best beneficial uses.	Similar to existing	Near historically approved disposal sites.
3F	Same as 3A, except dredge to total depth of 38 ft and with width 1,000 ft	Reasonable availability and capacities available, best beneficial uses.	Similar to existing	Large amount to be disposed.
3B (Migrating channel)	Modified S-curve (moderate curve)	Reasonable availability and capacities available, good beneficial uses.	Similar to existing	Near historically approved disposal sites.
3G (Migrating channel)	Same as 3B, except dredge to total depth of 38 ft and with width 1,000 ft	Reasonable availability and capacities available, good beneficial uses.	Similar to existing	Large amount to be disposed.
3H-a	Existing SR-105 dike	Reasonable availability and capacities available, best beneficial uses.	Slight reduction from existing	Near historically approved disposal sites.
3H-b	SR-105 dike raised to elevation -2 ft (3H-b)	Reasonable availability and capacities available, best beneficial uses.	Significant reduction from existing	Near historically approved disposal sites.
4A	Dredge primarily on entrance bar	Marginal availability and capacities available, good beneficial uses.	Slight reduction from existing	Side-casting necessary.
4E	Same as 4A, except dredge to total depth of 38 ft and with width 1,000 ft	Marginal availability and capacities available, good beneficial uses.	Slight reduction from existing	Side-casting necessary.

[1] Note: All channel depths are 26 ft mllw + 2 ft over-dredging (500 ft width at bottom) unless otherwise specified. Elevation referenced to mllw.